

DRL Number T-784  
Line Item 4  
MSC-03774 ,Addendum 1

Contract *CR-128949*  
Summary  
Report

May 1973

# Neutral Buoyancy Testing of a Shuttle Orbiter Crew Compartment

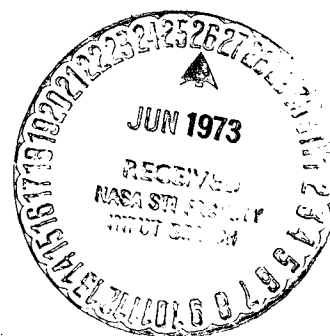
Approved by NASA

(NASA-CR-128949) NEUTRAL BUOYANCY TESTING  
OF A SHUTTLE ORBITER CREW COMPARTMENT  
Summary Report (Martin Marietta Corp.)  
21 p HC \$3.25

CSCD 22B

N73-25893

G3/31    Unclass  
05858



Prepared for  
National Aeronautics  
and Space Administration  
Johnson Spacecraft Center  
Houston, Texas

**MARTIN MARIETTA**

CONTRACT NAS9-11947(IS)

DRL NUMBER T-784 LINE ITEM 5

MSC-03774, ADDENDUM I

APPROVED BY NASA

CONTRACT SUMMARY REPORT  
FOR  
NEUTRAL BUOYANCY TESTING A  
SHUTTLE ORBITER CREW COMPARTMENT


MAY, 1973

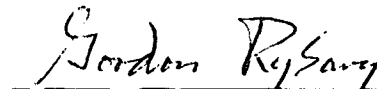
PREPARED BY:

A. A. ROSENER

M. L. STEPHENSON

APPROVED BY:

  
A. A. Rosener  
Program Manager, MMC  
NAS9-11947 (IS)

  
Gordon Rysavy  
NASA - JSC Technical Monitor  
NAS9-11947 (IS)

MARTIN MARIETTA CORPORATION  
DENVER DIVISION  
P. O. Box 179  
Denver, Colorado 80201

## FOREWORD

This report was prepared by the Martin Marietta Corporation under Contract NAS9-11947(IS), DRL T-784, Line Item 5, "Neutral Buoyancy Testing a Shuttle Orbiter Crew Compartment, for the Johnson Spacecraft Center of the National Aeronautics and Space Administration. The effort was administered under the technical direction of the Spacecraft Design Office with Mr. Gordon Rysavy acting as the technical manager. This report summarizes the effort performed during the period of this contract.

## TABLE OF CONTENTS

	<u>Page</u>
Foreword .....	ii
Table of Contents.....	iii
I. Introduction.....	1
II. Study Scope and Objective.....	1
III. Relationship to Other NASA Efforts.....	1
IV. Method of Approach and Principle Assumptions.....	1
V. Basic Data Generated and Significant Results.....	3
A. Basic Data Established.....	3
1. Couch Area Summary.....	3
2. Galley Summary.....	6
3. Personal Hygiene Summary.....	8
4. Airlock Summary.....	10
5. Flight Deck Summary.....	10
6. Time Lines.....	11
7. Dual, One/Zero Gravity Design Considerations.....	12
8. Zero-Gravity Man Model Definition.....	12
VI. Study Limitations.....	15
VII. Implications for Research.....	15
VIII. Suggested Additional Efforts.....	15

### Figures

IV-1 Shuttle Nose Test Mockup.....	3
V-1 Female Test Subject Reading in Passenger Couch in Horizontal One-Gravity Mode.....	4
V-2 Male Test Subject in Passenger Couch with Restraint Belts Connected Prior to Re-Entry.....	4
V-3 Crew Compartment Area With Passenger Couches Mounted in Y Direction During Simulated Zero-Gravity Mode...	5
V-4 95th Percentile Male Test Subject Sleeping in Passenger Couch During Horizontal One-Gravity Mode..	5
V-5 Entrance into Forward Passenger Couch From Ladder in Vertical One-Gravity Mode.....	5
V-6 In Simulated Zero-Gravity Mode Access Tests in Galley During Food Preparation.....	6
V-7 Male Test Subject in Galley Storing Food Tray in Horizontal One-Gravity Mode.....	6

<u>Figures</u>	<u>Page</u>
V-8 95 Percentile Male Test Subject Egressing From Galley During Simulated Zero-Gravity Mode.....	7
V-9 65 Percentile Male Test Subject Obtaining Access to Lower Drawer in Horizontal One-Gravity Mode.....	7
V-10 95 Percentile Male Test Subject Sitting on Commode with Mockup in Vertical One-Gravity Mode.....	8
V-11 95th Percentile Male Test Subject During Urination in Simulated Zero-Gravity Mode.....	8
V-12 65 Percentile Female Subject in Simulated Zero-Gravity Mode in Activating Hand Washing Foot Control Valve.....	9
V-13 70 Percentile Male Test Subject in Simulated Zero- Gravity Mode After Defecation, Wipe Sequence.....	9
V-14 50 Percentile Male Test Subject During Urination in Simulated Zero-Gravity Mode.....	9
V-15 65 Percentile Male Test Subject Sitting on 30 Degree Sloped Commode in Horizontal One-Gravity Mode.....	9
V-16 Crew Entry Into Flight Deck Area During Horizontal One- Gravity Mode.....	10
V-17 Entrance to Flight Deck From Crew Area During Vertical One Gravity Mode.....	10
V-18 5 and 95 Percentile Length During Zero-Gravity Soaring..	12
V-19 Degrees of Motion Possibilities.....	13
V-20 Stature Height Increases as Much as 5/8 of an Inch During Neutrally Buoyant Conditions.....	14

## I. INTRODUCTION

This contractual effort was initiated to study and analyze the architectural and man-machine aspects of a Shuttle Orbiter Crew Compartment as a total system. Previous studies of various habitability entities have been conducted and have established a beginning for Shuttle design criteria. Two recently conducted efforts, NAS9-10761, "Engineering and Architectural Study for Extraterrestrial Architectural Design" and NAS9-11947, "Neutral Buoyancy Testing of Architectural and Environmental Concepts of Space Vehicle Design" have added to the data base significantly. This effort examined all phases of the Orbiter's flight mode from launch through zero-gravity, re-entry and ferry flight. This data, integrated with previous efforts, provides an initial design criteria that considers the crew compartment as a total system and provides data that has a direct contribution to the development of flight hardware.

## II. STUDY SCOPE AND OBJECTIVE

The scope of the contract was to analyze, develop, fabricate and test by simulation the various flight modes of the NASA-JSC concept 040A version of the Shuttle Orbiter Crew Compartment. Primary interest was placed on the architectural aspects of the galley, hygiene facility, passenger couches, airlock, work station and flight deck access. The man-machine interface emphasis was placed on identifying and developing solutions for problems in mobility/restraint, ingress/egress, accessibility, and volume utilization.

The objective of this contract was to develop design criteria for a Shuttle Orbiter Crew Compartment concerning man-machine interfaces and architectural aspects. The design criteria was to be applicable to a crew of six and for the various orbiter flight modes of launch, zero-gravity, re-entry and ferry flight. The design criteria objective was to provide the Shuttle crewmen a functional and compatible habitat.

## III. RELATIONSHIP TO OTHER NASA EFFORTS

The design criteria developed under this contract has a direct relationship to the development of the Shuttle Orbiter Crew Compartment in the areas of the galley, hygiene facility, passenger couches, airlock, system station and flight deck access. Design criteria relative to mobility/restraint, volume utilization, ingress/egress and accessibility are also applicable to other manned space vehicles. The crew equipment man-machine interface is directly applicable to several hardware development contracts such as for personal hygiene equipment, galley equipment, passenger couches, and other crew equipment.

## IV. METHOD OF APPROACH AND PRINCIPLE ASSUMPTIONS

The study was conducted by Martin Marietta Corporation utilizing the following method of approach:

- o A design analysis was accomplished to obtain a thorough background knowledge on the various crew compartment configurations. These analysis consisted of examining shuttle nose configurations, crew/passenger requirements, task descriptions, ingress/egress procedures, equipment concepts/locations, volumetric requirements and orientations of the various module areas.
- o Performed preliminary neutral buoyancy tests to obtain detailed design

information concerning foot restraints and NASA-JSC supplied passenger couch. Test results were incorporated into the design concepts.

- o The data generated from the analysis was integrated with the basic NASA-JSC crew compartment concept 040A. Design concept drawings were prepared for fabrication purposes.
- o Fabricated a full scale mockup that was structurally able to be tested with the x-axis both vertical and horizontal in an earth environment. In addition, the mockup was constructed of materials compatible for neutral buoyancy testing to simulate a zero gravity environment. The full scale mockup was furnished with modules of the various areas so that these modules could be moved for different arrangements and orientations. These modules included a galley, personal hygiene, passenger couches, airlock, and a work station. Each of these modules had both operable and simulated furnishings for man-machine interface purposes that completely satisfied the test requirements.
- o Detailed test procedures were prepared listing step-by-step tasks that ensured that each component item, as well as the total component volume, was completely evaluated in all three modes of testing.
- o Evaluated and assessed test data utilizing subject and observer's comments, still photographs, 16mm movie films, and TV video tape. Specific analysis was prepared on the volumetric/size allotment, mobility and restraint definition, and probable design problems.
- o Prepared final documentation that summarized entire contract efforts. In addition, prepared Supplement II to the "Architectural/Environmental Handbook," MSC-03909, and Supplement II to the "Handbook Rationale", MSC-01532.

The principle assumptions for this effort included the following:

- o The Shuttle Orbiter configuration is the basic NASA concept 040A.
- o The total number of personnel considered during this study is ten (10) maximum. This consists of a crew size of two (2) to four (4) with six (6) passengers. The personnel were considered to be a mixed crew of males and females.
- o The mission duration for the Shuttle Orbiter is a total of seven (7) days in the 1978 - 1985 time period.
- o The crewmen would be launched on the flight deck and the six passengers would utilize the passenger couches for their launch support.
- o Both the crewmen and passengers would utilize the crew compartment to accommodate their general habitability tasks of work, sleep, eating, personal hygiene functions, and relaxing.
- o The atmosphere was considered to be a shirtsleeve environment through all phases of mission. Provisions for a suited crewman were made for all main passageways and the airlock.



The resultant Shuttle nose configuration generated from the principle assumptions is illustrated in Figure IV-1. The various series of test conducted utilized this test mockup in two positions - horizontal and vertical. The illustration shows the mockup during the horizontal one-gravity test setup.

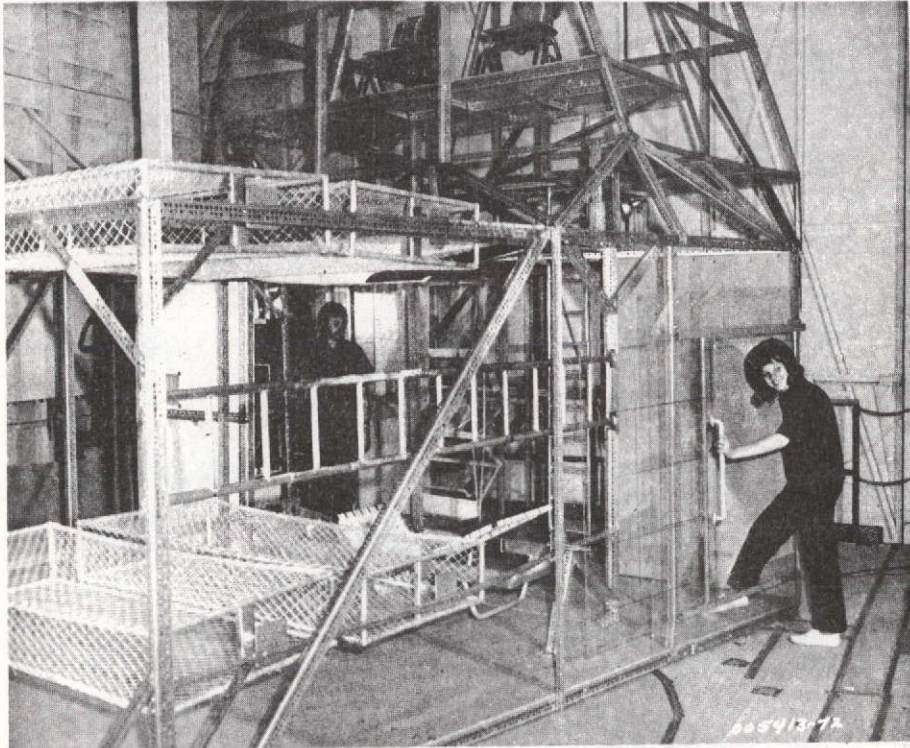


Figure IV-1 Shuttle Nose Test Mockup

## V. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

### A. BASIC DATA ESTABLISHED

The data generated during this contract was primarily for man-machine interface and considerations applicable to a manned vehicle in a dual gravity environment. The pertinent design data was published as a second supplement to the "Architectural and Environmental Handbook", NASA-JSC Document 03909. This contract included the development of man-machine interfaces for a galley, personal hygiene facility, crew/passenger couch area, airlock, work station, and flight deck access. The data presented was based on results obtained from the testing phase of this contract. The following paragraphs are a summary of the parameters tested:

#### 1. Couch Area Summary

- a. Merits - Area provides adequate mounting provisions and ample room for all couch functions; all controls were within easy reach and good visibility; toe rail and lap belt provided adequate support in simulated zero-g; both male and female subjects were able to operate equipment and gain access to the couches.



- b. Defficiencies - In one-g horizontal mode, it was difficult to gain access to the forward and upper couches; could not use clerical tray for eating in the one-g mode; it was difficult to gain access to and enter the couches; no package handling or servicing could be accomplished in the forward section; backward foot pan adjustment, poor seat pan adjustment control.
- c. Access Factors - Aisle size, mobility aids, and access volume for each couch.
- d. Factors Affecting Design Concept - Incorporation of restraint/mobility aids in the couch and surrounding structures; couch positioning devices and control location; access ladders and servicing platforms.

These points are illustrated in the Figure V-1 thru V-5

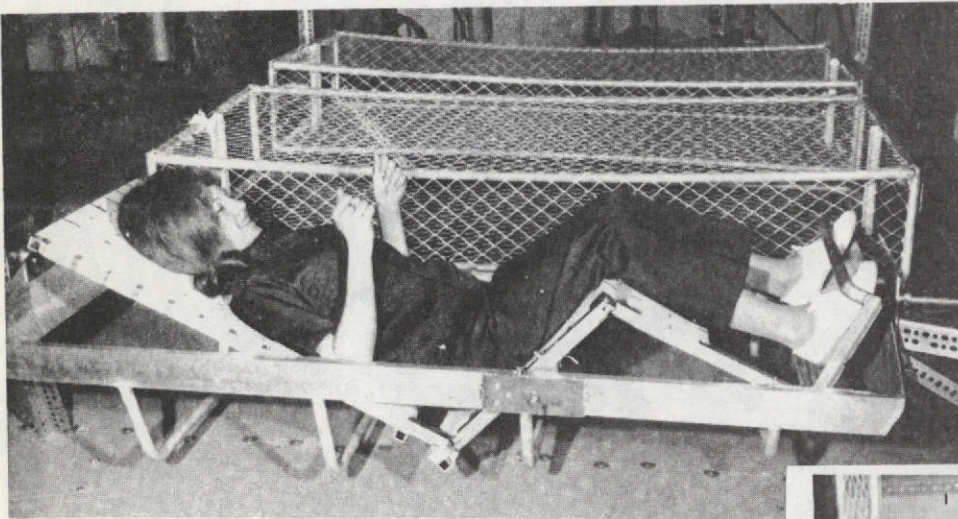


Figure V-1 Female Test Subject Reading in Passenger Couch in Horizontal One-Gravity Mode



Figure V-2 Male Test Subject in Passenger Couch with Restraint Belts Connected Prior to Re-Entry





Figure V-3 Crew Compartment Area With Passenger Couches Mounted in Y Direction During Simulated Zero-Gravity Mode



Figure V-5 Entrance into Forward Passenger Couch from Ladder in Vertical One-Gravity Mode

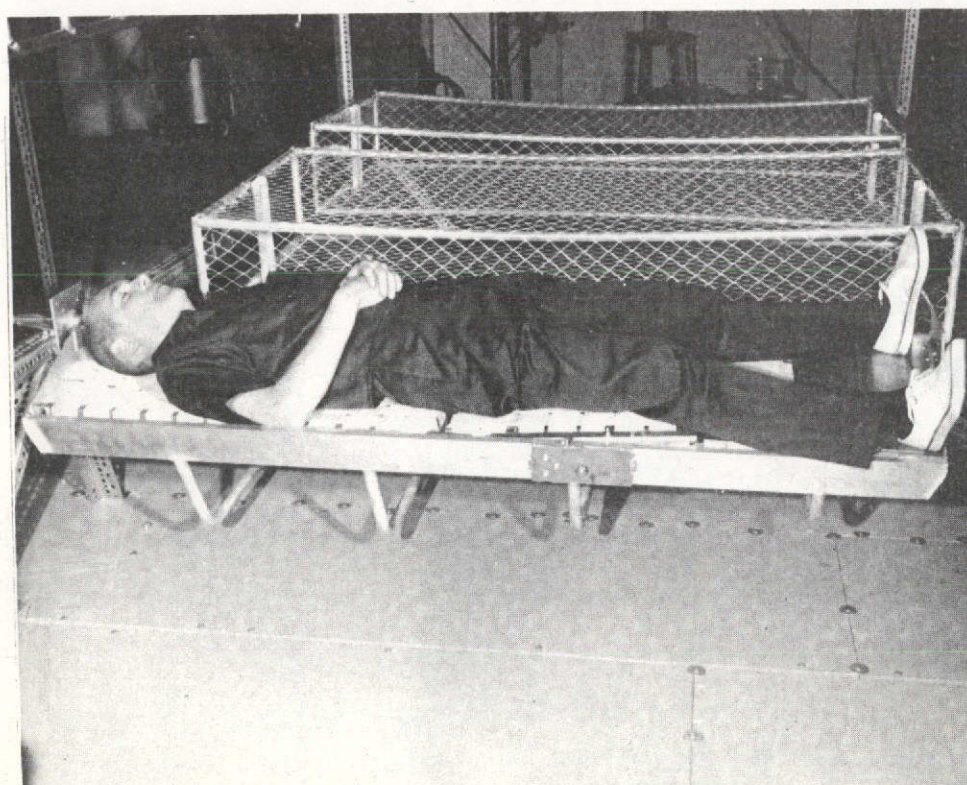


Figure V-4 95th Percentile Male Test Subject Sleeping in Passenger Couch During Horizontal One-Gravity Mode



## 2. Galley Summary

- a. Merits - Layout of module permits simple foot rail and counter hand rail as only mobility/restraint aids required to perform all tasks.
- b. Deficiencies - On module egress, it would be desirable to have mobility aids built into the structure on each side; waist restraint was unsatisfactory as it pulled the body against counter which restricted movement and view; the galley module usage and servicing is restricted in the Shuttle vertical position without an access platform;
- c. Access Factors - Equipment storage areas below knee level (22 inches) should be pull-out drawers for visibility and accessibility of contents; storage areas above 54 inches from floor should be swing-out doors for access; storage areas between 22 inches and 54 inches from the floor can be of any type access (swing-out, sliding, drawer); counter space height should be located 40 inches above floor. Personal usage and high usage areas and equipment should be placed between 30 inches and 54 inches from the floor.
- d. Factors Affecting Design Concepts - Test subjects utilized three different modes of egress; some utilized the foot rail by squatting, orientating body toward desired direction and pushing off with hands/arms extended straight out; others pushed off the front refrigerator/freezer door in same manner; the third technique was to turn and grasp the galley side structure at entrance and pulled with their hands.

These aspects of the galley operation are depicted in the Figure V-6 thru V-9.



Figure V-6 In Simulated Zero-Gravity Mode Access Tests in Galley During Food Preparation

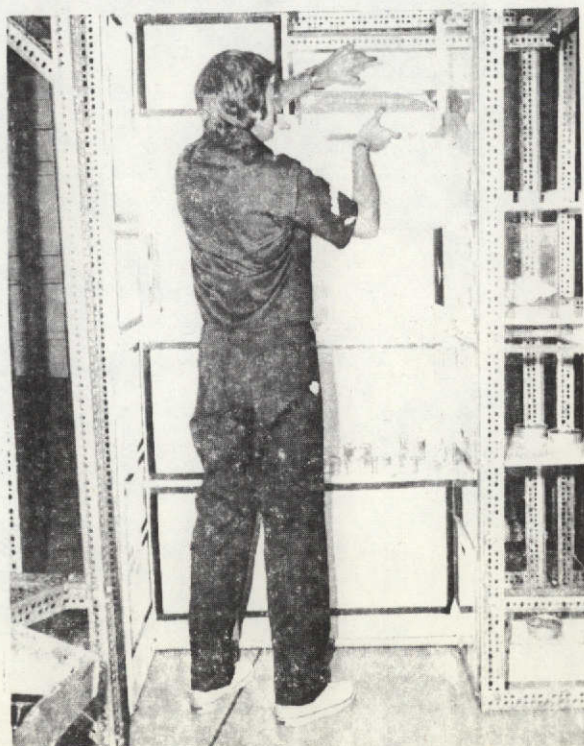


Figure V-7 Male Test Subject in Galley Storing Food Tray in Horizontal One-Gravity Mode





Figure V-8 95 Percentile Male Test Subject  
Egressing From Galley During  
Simulated Zero-Gravity Mode



Figure V-9 65 Percentile Male Test Subject  
Obtaining Access to Lower Drawer  
in Horizontal One-Gravity Mode



### 3. Personal Hygiene Summary

- a. Merits - Module is optimum in a weightless environment, usable in one gravity horizontal position, and almost non-usable in vertical one gravity position; provided good temporary clothes stowage; toiletry kit display area good for one-g and zero-g; hand wipes and dispenser location good for one-g and zero-g.
- b. Deficiencies - In the vertical on-pad position, handwasher basin is rotated  $90^{\circ}$  to normal and is therefore unusable; mirror is usable only by subject turning head  $90^{\circ}$  and leaning far back when seated on commode; entire 78 inch height is wasted; very difficult to perform any servicing/maintenance since height is 30 inch. The egress/ingress in this position is difficult due to not being able to stand vertical in only a 30 inch height. Subjects cannot seat comfortable on commode due to 30 inch head height; feet are on angle and therefore subject cannot raise to perform wiping act; pulling up clothes must be effectively accomplished outside the module.
- c. Access Factors - Door design and operation; wipes location; controls location and operation mode.
- d. Factors Affecting Design Concept - Areas below knee level (22 inches) shall be pull-out drawers; urinal height to be a nominal 36.4 inches; maximum angle of commode seat for one-gravity usage is 30 degrees from the horizontal ; use of tambour doors alleviate need for restraint handhold by door; requires two toerails at different elevations to accommodate the 5 thru 95 percentile male for urination.

The use of the personal hygiene facility is shown in the Figures V-10 thru V-15.

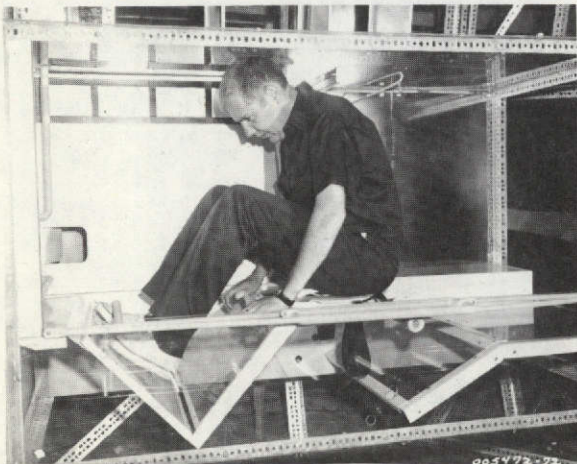


Figure V-10 95 Percentile Male Test Subject Sitting on Commode with Mockup in Vertical One-Gravity Mode



Figure V-11 95th Percentile Male Test Subject During Urination in Simulated Zero-Gravity Mode





Figure V-12 65 Percentile Female Subject in Simulated Zero-Gravity Mode in Activating Hand Washing Foot Control Valve



Figure V-13 70 Percentile Male Test Subject in Simulated Zero-Gravity Mode After Defecation, Wipe Sequence



Figure V-14 50 Percentile Male Test Subject During Urination in Simulated Zero-Gravity Mode



Figure V-15 65 Percentile Male Test Subject Sitting on 30 Degree Sloped Commode in Horizontal One-Gravity Mode



#### 4. Airlock Summary

- a. Merits - The one meter hatch size was more than adequate for ingress/egress in either shirtsleeve or pressure suit; volume was more than adequate for two people and the donning/doffing of pressure suits; the large (1 inch diameter) operating hatch handle was easy to operate even with pressure suit.
- b. Deficiencies - Lack of ancilliary equipment within the airlock prevented a true evaluation of the interior volume; required more restraints in the form of toe rails and handholds.
- c. Factors Affecting Design Concept - Ancilliary equipment; hatch size and opening technique; location and type of restraint/mobility aids; hatches must be positioned in a manner that allows maximum volume utilization.

#### 5. Flight Deck Summary

The flight deck was only evaluated with respect to access to the area. However, in the vertical one-gravity mode several problem areas were encountered in gaining access to the area and the pilot/co-pilot seats. This is illustrated in Figures V-16 and V-17.



Figure V-16 Crew Entry Into Flight Deck Area During Horizontal One-Gravity Mode

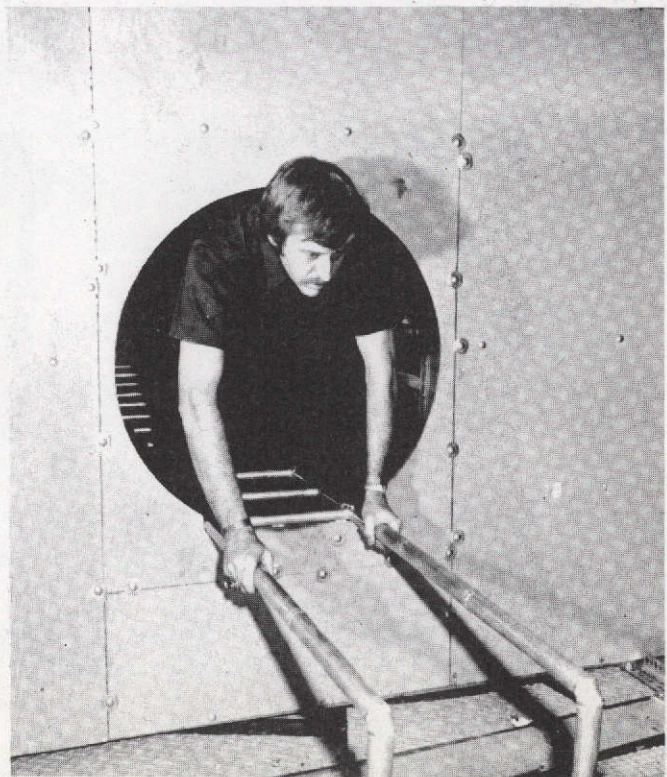


Figure V-17 Entrance to Flight Deck From Crew Area During Vertical One Gravity Mode



## 6. Time Lines

Time required for various tasks was obtained during the various phases of testing and are provided in Table V-1. It is significant to note that generally times required to perform the same task in a simulated zero-gravity environment were longer than when performed in the one-gravity sequence. The exception was during locomotion from the exit hatch to the flight deck and egressing from the work station to the top couch in the vertical one-gravity mockup mode. In both cases, the subjects had to climb ladders in the one-gravity mode whereas in the simulated zero-gravity mode the subjects could use the ladders as mobility aids. Times were generally higher for the vertical one-gravity mode when compared with the horizontal one-gravity mode due to climbing over objects and up ladders. The exception to this was when the subjects egress from the lower couch to the exit hatch. During the vertical one-gravity mode, the subjects simply swing from the lower couch onto the work station wall and exited through the hatch.

Table V-1 Times Versus Tasks

TASK	TEST PHASE OF MOCKUP		
	HORIZONTAL ONE-GRAVITY (Seconds)	VERTICAL ONE-GRAVITY (Seconds)	SIMULATE ZERO-GRAVITY (N.B.) (Seconds)
A. Locomotion:			
1. Exit Hatch to:			
a. Payload Station	8	10	--
b. Flight Deck	20	55	23
c. Lower Couch	15	17	--
d. Upper Couch	--	11	--
2. Exit Hatch From:			
a. Flight Deck	7	20	27
b. Lower Couch	15	6	--
c. Upper Couch	--	13	--
B. Couch Functions			
1. Sitting to Sleeping	9	9	20
2. Egress Obtain Food Tray	11	--	25
3. Ingress From Galley	13	--	18
C. Galley Functions			
1. Scullary	48	--	70
D. Personal Hygiene			
1. Ingress Thru Door	3	7	13
2. Close Door	2	--	4
E. Airlock			
1. Ingress			
a. One Man	--	--	27
b. Two Men	--	--	45
2. Donning Pressure Suit	--	--	99
F. Work Station			
1. Egress to Top Couch	--	11	10

## 7. Dual, One/Zero Gravity, Design Considerations

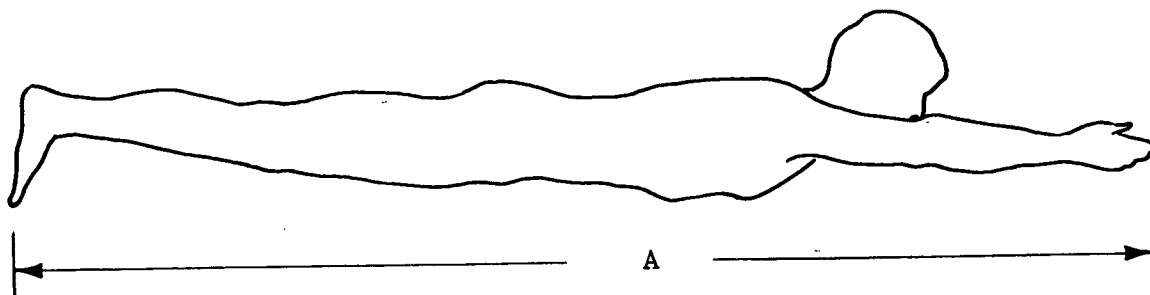
Several areas exist where specific design criteria for a vehicle which must operate in two orientations of one-gravity and zero-gravity environments have been identified. Those criteria are presented in the following paragraphs with a brief discussion of each area.

- o Locomotion - Movement from one point to another in a vehicle that operates in the dual environments of one and zero gravity will be dictated primarily by the one gravity mode. The design for the transfer of personnel and equipment when the vehicle is in a verticle position is deemed to require the more extensive aids.
- o Door/Hatchway Design - The design of doors and hatchways for one/zero-gravity dual usage is again dictated primarily by the requirements of the one-gravity environment because the minimum sized doors/hatchways for one gravity are more than adequate for the zero-gravity environment. However, the technique employed in opening or closing a door/hatchway is directly affected by the design and the required access volume to a room, module, or area.
- o Furniture Design - The design of specific furniture items for one/zero-gravity dual usage is dictated primarily by the functional requirements of one gravity and the greater than one-gravity loads imposed by launch, reentry, landing, and crash conditions.

## 8. Zero-Gravity Man Model Definition

The following data further defines the characteristics of a man in a zero-gravity environment. This definition is provided to make the designer aware of man's actions in this environment which could effect the man-machine interface design.

- a. Translation in Large Volume - During translation along a path greater than the body stature length, the subject usually pushes off with his feet, soars approximately parallel to the defined path with his head tilted back such that his eyes are also parallel to the path. The arms and hands are extended parallel to the path which in effect lengthens the body envelope dimensions. This is illustrated in Figure V-18.



A=81.5 inches for 5 Percentile  
A=92.4 inches for 95 Percentile

Figure V-18 5 and 95 Percentile Length During Zero-Gravity Soaring

- b. Translation in Small Volume - Zero-gravity maneuvering in a small volume, such as a personal hygiene module is usually accomplished with the body orientated to the task to be accomplished. The hands and arms are used extensively during the maneuvers with the feet utilized only for restraint and stabilization.
- c. Degrees of Motion - Five degrees of body motion are primarily utilized in the locomotion process. These are translation in X, Y and Z planes, pitch about x-axis and yaw about the z-axis. Roll about the y-axis is seldom utilized. See Figure V-19.

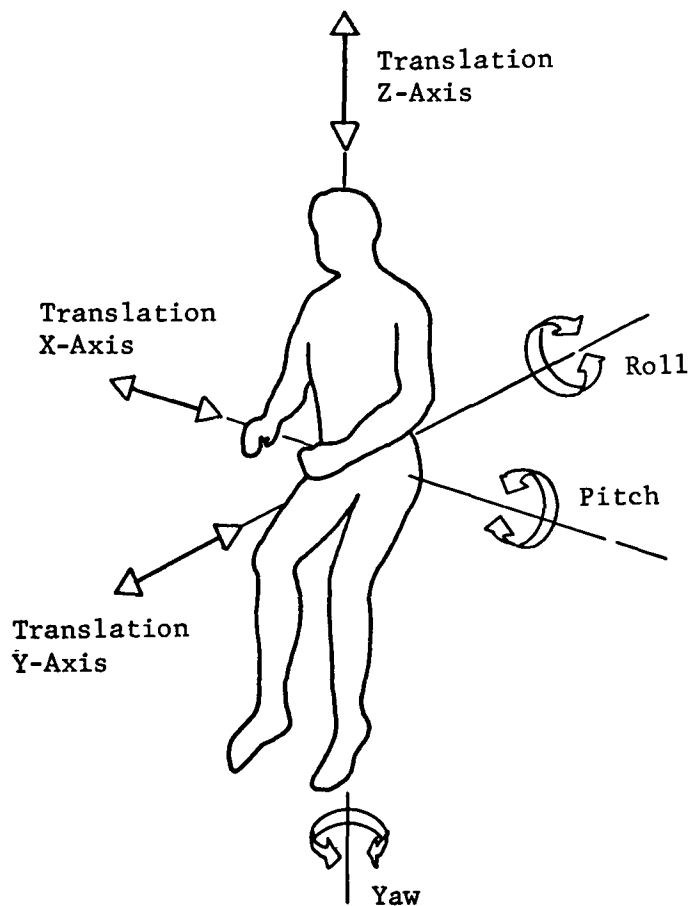


Figure V-19 Degrees of Motion Possibilities

- d. Mobility/Restraint - In a zero-gravity environment, the hands and arms are utilized to a greater extent during locomotion than in one gravity. The feet are normally utilized as mobility aids for propelling, whereas the hands are utilized for guidance.

- e. One-Gravity Versus Zero-Gravity Usage of Limbs - In one gravity, the heels and ball of the feet are utilized during the locomotion and stabilization process. In zero gravity, the heels of the feet are utilized less and the ball of the foot and the toes are utilized more. During zero-gravity stabilization, the leg muscles are utilized much more than in one gravity standing. The calf and upper leg muscles are primarily affected.
- f. Increase Stature Height - In the absence of gravity, actual body measurements of the stature height is increased. Neutrally buoyant conditions increase the stature height as much as  $\frac{5}{8}$  of an inch. In true zero gravity, this stature height may be increased even more. See Figure V-20.

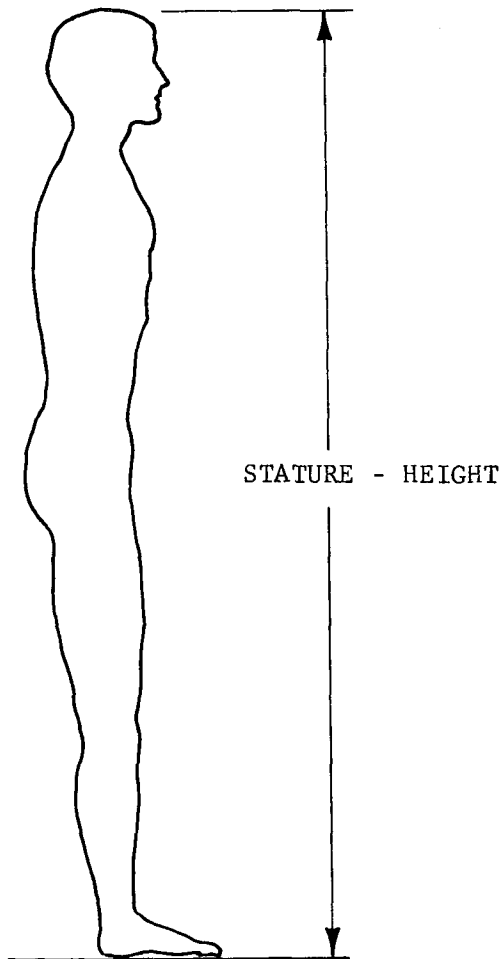


Figure V-20 Stature Height Increases as Much as  $\frac{5}{8}$  of an Inch During Neutrally Buoyant Conditions

## VI. STUDY LIMITATIONS

The limitations associated with this study include the following:

- o The low fidelity of the flight deck and airlock modules prevented a complete assessment of all the man-machine interfaces.
- o The time of all test simulations for the various tasks was of a relative short duration. Longer duration tests would define other man-machine interfaces.
- o During mobility maneuvers, the water drag on the subject's bodies did not simulate an actual zero-gravity environment. In addition, the subjects could make 90 degree turns easier without the aid of mobility/restraint aids.

## VII. IMPLICATIONS FOR RESEARCH

During performance of the contract, the following areas have been identified as having implications for research:

- o Man's Stature Growth - Man's stature height dimension varies with attitude (prone/standing) and the time (morning/evening) in a one-gravity environment. In a zero-gravity environment, this stature height could remain the same or increase due to the lack of the gravity environment. This could effect some man-machine interfaces such as garment design, sleep restraints, urinal heights, or task volume requirements.
- o Task Forces - Forces required to perform various habitability type tasks with the use of various restraints should be investigated to determine specific design criteria on loads that can be applied. These investigations should consider each of the body limbs in the body positions of standing, bending, stooping, squatting, kneeling, prone, and supine.

## VIII. SUGGESTED ADDITIONAL EFFORTS

It is recommended that the following related additional efforts be accomplished:

- o Flight Deck Evaluation - It became obvious during both one-gravity on-pad vertical and simulated zero-gravity neutral buoyancy tests that there were several interferences between the test subjects and equipment on the flight deck. These interferences should be fully evaluated with a high fidelity mockup of the flight deck equipment and crewmen performing the tasks associated with that area. Both vertical-on pad and neutral buoyancy evaluation tests should be conducted.
- o Rockwell Configuration - It would be desirable to perform similar tests on the actual Rockwell Shuttle Orbiter Crew Compartment Configuration as was performed on this contract. Probable design problems could be identified and corrected prior to fabrication efforts. Emergency egress problems could also be identified for their impact on the equipment design.

- o Manned Payload Module - If the available crew compartment volume dictates that it cannot accommodate passengers and payload specialists, it would be desirable to define a Manned Payload Module that would accommodate these personnel through all phases of the Orbiter's Mission. Based upon preliminary investigations, some proposed payload experiments require more personnel than the current baseline of four.
- o Mission Specialist Station - The mission specialist station should be more thoroughly defined from the viewpoint of the man-machine interface. Requirements, conceptual layouts, hardware definition and payload interfacing needs are partial criteria that need to be established prior to hardware development.
- o On-Pad Launch GSE Requirements - When the Shuttle Orbiter is in a verticle on-pad launch configuration, various ground support functions (GSE) are required. These GSE requirements consist of items related to check out, servicing and maintenance. These proposed tasks should be fully investigated to define servicing platforms and restraints as well as to determine the feasiability of the methodology.
- o Manipulator Station - The proposed manipulator station should be fully mocked up and evaluated for the man-machine interfaces.
- o Mini-Passenger Couch - Develop a mini-passenger couch for the crew compartment that would permit passengers and mission specialists to be safely launched. This mini-passenger couch would take less volume than present designs but serve the same purposes.